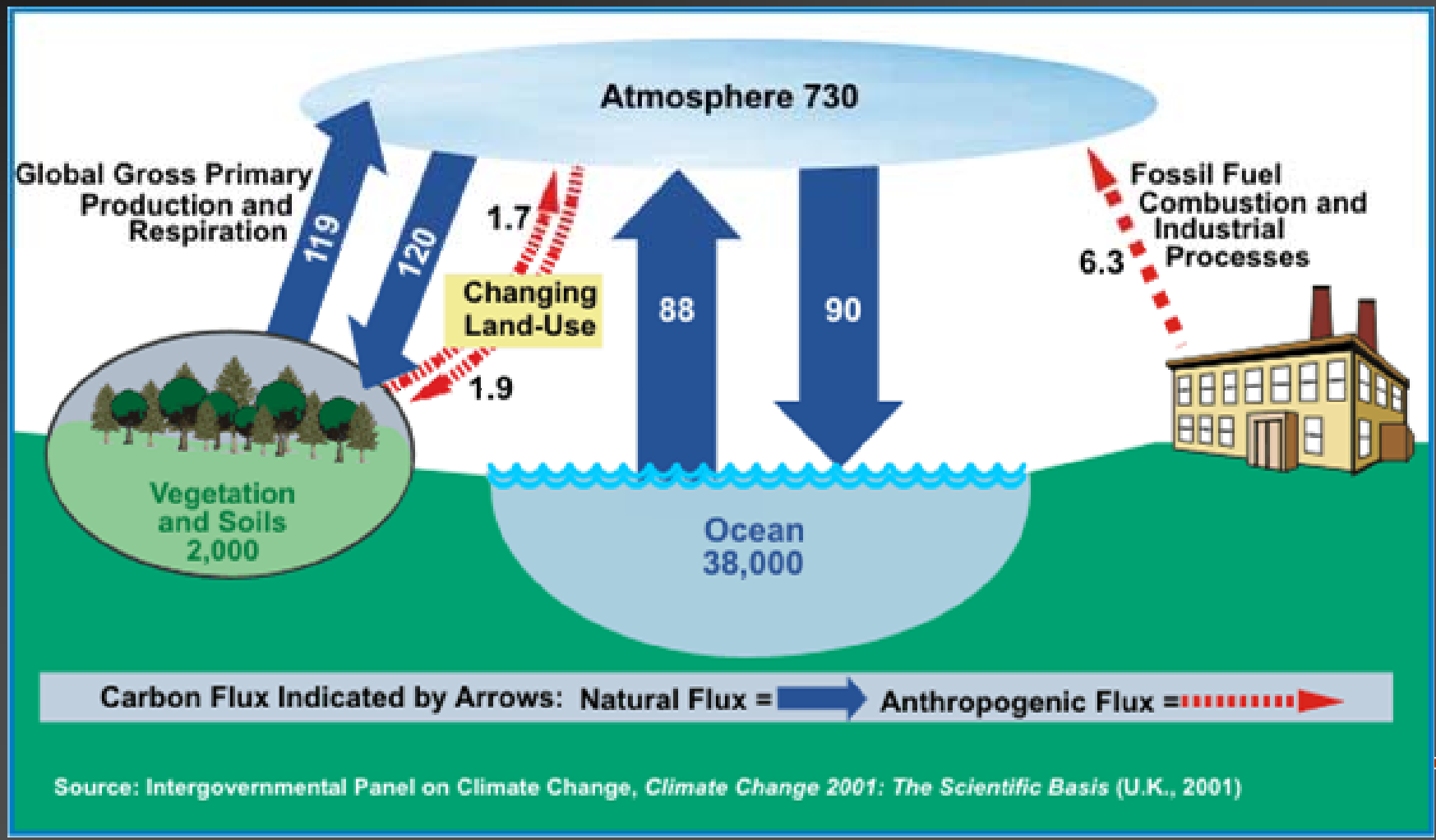
A Rapporteur's Observations

4th Annual Conference on Carbon Sequestration

Initial Observations

- Great progress in a short time
  - Workable technologies applied to demos/pilots and commercial enterprises
    - Carbon being sequestered
    - Developing data to support site selection criteria and monitoring and verification methodologies
  - Key technology hurdles identified
  - Preliminary surveys of potential storage capacity
  - International cooperation underway via IEA, CSLF, IPCC Special Report on CC&S and bilaterals to address global issue
- Taking the first steps toward enabling CC&S to play a meaningful role in global GHG stabilization

Context


Atmosphere 730
Global Gross Primary Production and Respiration
119
120
1.7
Changing Land-Use
1.9
88
90
Fossil Fuel Combustion and Industrial Processes
6.3
Vegetation and Soils 2,000
Ocean 38,000
Carbon Flux Indicated by Arrows: Natural Flux =
Anthropogenic Flux =
Source: Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (U.K., 2001)

What We've Been Talking About

- Technical
  - Storage Capacity and Permanence
  - Site Selection / Option Selection
  - Separation and Capture
  - Sequestration Options
  - Transportation
  - Monitoring and Verification
  - Risk Assessment
- Economic
  - Cost
  - Value
- Regulatory
  - International framework, national implementation
  - Accounting
- Public Acceptability

Capacity

- Is there enough “long-term” storage available for CC&S to:
  - make a meaningful contribution toward stabilization?
  - become a “bridge” to a hydrogen economy?
  - enable use of fossil fuels to become “carbon neutral”?
- Current surveys of potential include > “order of magnitude” uncertainty (top-down vs bottom-up)
- Each site unique – large body of knowledge and assessment tools needed
- What does “long-term” storage mean?

Site / Option Selection

- Some sites adequately characterized to provide confidence (e.g., oil fields successfully flooded)
- Some sites too “leaky” or difficult to seal
- Abandoned wells and mine shafts may offer leakage pathways
- Vast majority of options not well enough characterized to be confident suitable for “long term” storage

Need accepted tools and protocols for diverse conditions

Separation and Capture

- Opportunities
  - Pre-combustion de-carbonization
  - Post-combustion
- Techniques
  - Adsorption
  - Absorption
  - Membranes
  - Cryogenics
  - Oxy-Fuel (CO_2-O_2 recycle)
  - Novel Techniques

Cost, Efficiency and Scale must improve for all

Sequestration Options

- Geologic
  - Unmined / Depleted Coal Seams; Oil and Gas Fields
  - Deep Saline Formations
- Terrestrial
  - Agricultural Soils and Plants
  - Forest Management and Reforestation
  - Biogenic Gas Management
- Ocean
  - Zooplankton / Photoplankton nourishment
  - Deep ocean injection
  - CO2 Hydrate Composite Plumes
- Novel Techniques
  - Ex-situ mineralization
  - Genetically engineered organisms

Transportation

- Point sources and containment sites not usually co-located (e.g., Middle East could import CO_2)
- Pipelines in use (U.S. moves 45M t/y) and traverse hundreds of miles (CENS project in North Sea, TX)
- Ships can transport small quantities

Infrastructure needs optimization; technology adequate

Monitoring and Verification

- Need high confidence of stable long-term storage
- Inventory verification, leak detection over time
- Techniques
  - Seismic – not suitable in all situations
  - Monitor wells
  - Test probes
  - Surface leakage using flux meters, soil gas sampling
  - Standard oil field practice – injection and production

Need accepted tools and protocols for all storage options and conditions

Economics

- CC&S is not without cost
- Value of CC&S must exceed cost
- Most CO_2 injection projects currently EOR driven (e.g., 70+ in U.S.)
- Global carbon value $10 to $20/ton depending on whether carbon emissions are constrained
- Reduced CC&S costs and higher carbon value incentivize more sequestration

Regulatory

- Regulations for current EOR projects are adequate.
- A new regulatory framework needed to enable the market trading of carbon credits.

Public Acceptance

- Important lessons on public acceptance can be learned from current oil and gas projects injecting CO_2
- Public largely unaware and probably indifferent unless directly affected
- Renewable energy and efficiency perceived as competitive with CC&S
- NIMBY?

Public education describing technology, risks and benefits needed

Summary

- Three successful industrial scale projects underway.
- Key technical obstacles to more efficient carbon capture and sequestration processes are reasonably well understood and under study.
- Much work remains to quantify viable storage capacity in order for CC&S to:
  - move beyond near-term funded demonstrations, or
  - be accepted as a key component of the atmospheric GHG stabilization strategy.
- Much work remains to develop scientific understanding, technical tools and protocols to satisfy regulatory agencies the public that sequestration is reliable and safe.

Comments

Email comments to:

carbonsq@exchangemonitor.com